

Dramé, Cheikh

Conference Paper

Resolving West Africa's electricity dilemma through the pursuit of smart grid opportunities

20th Biennial Conference of the International Telecommunications Society (ITS): "The Net and the Internet - Emerging Markets and Policies" , Rio de Janeiro, Brazil, 30th-03rd December, 2014

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Dramé, Cheikh (2014) : Resolving West Africa's electricity dilemma through the pursuit of smart grid opportunities, 20th Biennial Conference of the International Telecommunications Society (ITS): "The Net and the Internet - Emerging Markets and Policies" , Rio de Janeiro, Brazil, 30th-03rd December, 2014, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/106833>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

Resolving West Africa's electricity dilemma through the pursuit of smart grid opportunities

Cheikh Dramé
Independent Researcher

Author Note

Cheikh Dramé is now Finance Rotational Associate at Johnson Control Inc.

I am grateful for the support, valuable comments and suggestions of Dr. Sandra Braman (Department of Communication at University of Wisconsin-Milwaukee) and Binta Zahra Diop.

Comments and questions should be directed to:

Cheikh Dramé

Independent Researcher

Tel.: +1 (414) 779 7763

E-mail: cheikhpapydrame@gmail.com

Abstract

The electricity sector in West Africa provides power supply to only about 30% of the population (WAPP, Business Plan 2012 - 2015, 2012). The West African electricity dilemma refers to poor access to electricity due to an amalgamation of constraints primarily emanating from the regulatory environment and the demand and supply side of the electricity sector. This paper reviews the pertinent literatures in order to identify and communicate constraints upon access to electricity in the region, considered low by world standard. In order to alleviate West Africa's electricity dilemma, this paper suggests the pursuit of smart grid opportunities such as off-grid small-scale renewable energy technologies (RETs), smart meters, power line communication, metered-based tariffs and prepayments via mobile phones. The conceptual framework used in this paper integrates interrelated socio/economic aspects, regulatory aspects, financial aspects, and technical aspects deemed fundamental to successfully deploy smart grid technologies in West Africa, with Côte d'Ivoire as a case study. Telecommunications will play a key role in leveraging benefits of smart grid. The next step in this research will be to conduct interviews with stakeholders of the West African electricity sector as a mean to verify the extent to which smart grid opportunities are realizable in the region and enrich what can be learned through secondary research with what can only be learned from those active on the ground.

Keywords: Electricity Access, Electricity Dilemma, Smart Grid, Telecommunications, West Africa

Table of Contents

1. Introduction	3
2. West Africa electricity dilemma	4
2.1. <i>Regulatory aspects constraints</i>	5
2.2. <i>Electricity demand side dilemma</i>	8
2.2.1. <i>Social aspects constraints</i>	8
2.2.2. <i>Economic aspects constraints</i>	9
2.3. <i>Electricity supply side dilemma</i>	11
2.3.1. <i>Financial aspects constraints</i>	11
2.3.2. <i>Technical aspects constraints</i>	13
3. Conceptual framework	15
4. Smart grid opportunities for West Africa	16
4.1. <i>Socio-economics aspects opportunities</i>	17
4.2. <i>Regulatory aspects opportunities</i>	19
4.3. <i>Financial aspects opportunities</i>	20
4.4. <i>Technical aspects opportunities</i>	22
5. Smart grid technologies deployment in Côte d'Ivoire	23
6. Conclusion and future study	24

1. Introduction

The total population of West Africa is estimated around 330.7 million in 2013 (Population Reference Bureau, n.d.) with an average annual population growth rate of 2.7% ranking among the highest in the world (WAPP, Business Plan 2012 - 2015, 2012). In 2011, an estimated average of 60% of the total population resided in rural areas (WAPP, Business Plan 2012 - 2015, 2012). However, by 2050, 63% of the West African population will reside in urban areas (UN Population Division, 2014). This urban growth will be driven by rural exodus and it will boost electricity demand in cities. Today, nearly 70% of the West African population does not have access to electricity in a region where electricity supply is far from meeting demand. This is due to technical constraints such as insufficient generation, transmission and distribution losses, as well as financial constraints faced by utilities such as costly fuel driven by high prices of petroleum products (WAPP, Business Plan 2012 - 2015, 2012) and the lack of adequate financing. Moreover, poor electricity access in West Africa is caused by regulatory constraints in the electricity sector originating from weak regulatory frameworks and lack of policy incentives that are pro-energy efficiency.

West Africa's electricity dilemma relates to the region's poor electricity access due to an amalgamation of regulatory, social, economic, financial and technical constraints. As a solution to resolve the electricity dilemma, I propose the deployment of smart grid in West Africa. I define smart grid as the integration of renewable energy sources and information and communications technology (ICT)¹ through the power grid enhancing generation, transmission, distribution, storage and access to electricity. Moreover, I adopt the definition provided by Stephen Connors² who defines smart grid as the high voltage systems that all our power plants are hooked up to, the network integrating smart meter technologies, and the medium voltage systems fueled by renewable energy sources (MIT, 2013). Smart grid can save significant amount of lost power supply to feed unconnected customers in Africa and it is the future of electrical systems (Elhag, 2014).

So far, little research is published on smart grid opportunities in sub-Saharan Africa needless to say in West Africa. Research topics focusing on smart grid is recent and it is growing. In (Fadaeenejad, et al., 2014), based on data from ISI Web of Knowledge, Fadaeenejad observes that before 2008 there were less than 50 papers published annually on smart grid related topics. Afterward, research on smart grid skyrocketed. The advent of the first Africa Smart Grid Forum which took place from 14-16 May, 2014 in

¹ In section 5, I will emphasize the potential of telecommunications for leveraging smart grid from a user perspective in West Africa.

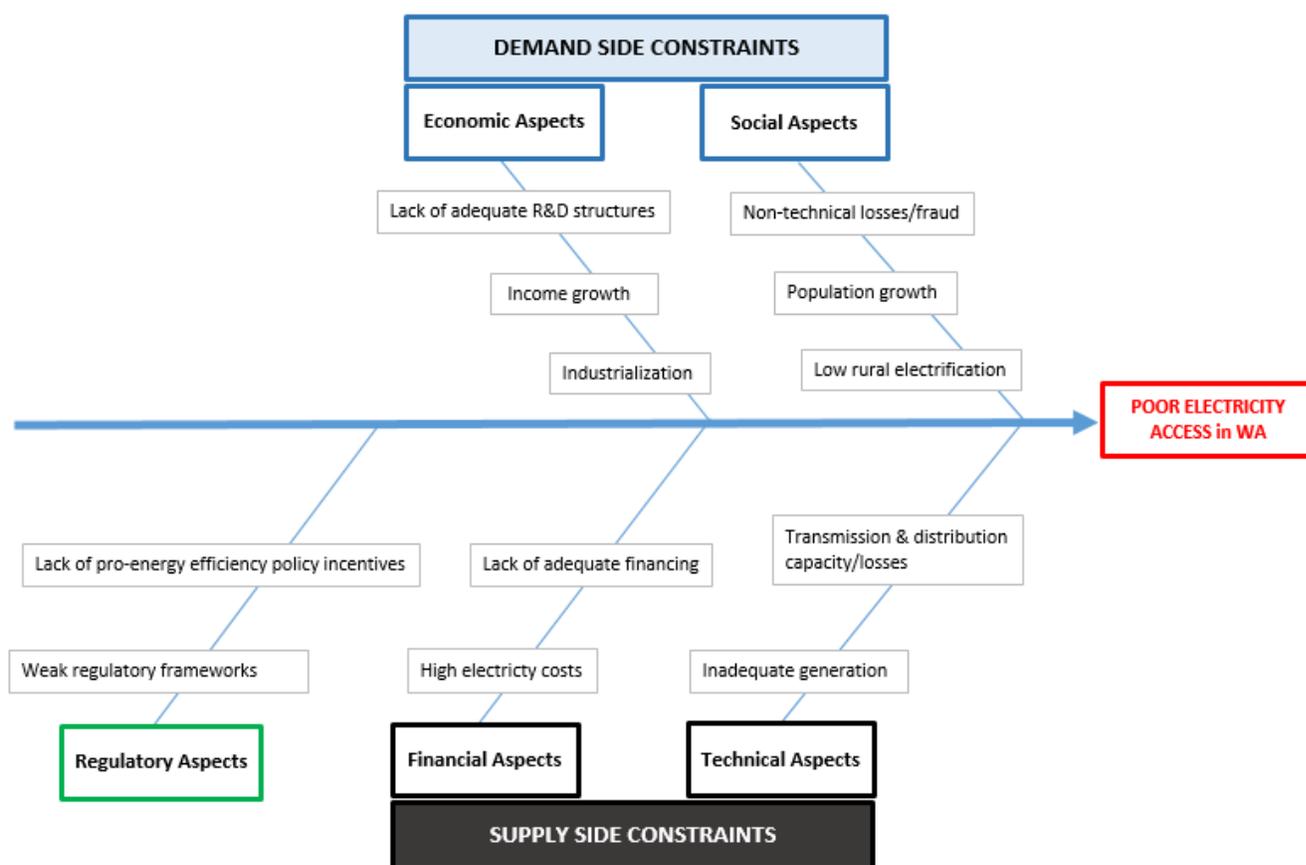
² Director of the Analysis Group for Regional Energy Alternatives (AGREA).

Abidjan, Côte d'Ivoire testifies of growing interests and considerations that electricity experts bequeath on smart grid as a solution for an emerging Africa. This study represents an initial set of thoughts to support future research and discussion on smart grid deployment opportunities in West Africa. This piece is addressed to consumer groups, civil society organizations, electricity sector experts, policy-makers, governments, international donors and researchers.

The remainder of the paper is organized as follows: in section 2, the paper reviews the pertinent literatures which introduce constraints causing poor electricity access in West Africa. Section 3 presents the conceptual framework for the research. Section 4 introduces smart grid deployment opportunities for West Africa based on the integration of socio/economic aspects, regulatory aspects, financial aspects, and technical aspects. Section 5 provides information on smart grid technologies deployment in Côte d'Ivoire, a West African country. A case study with Côte d'Ivoire is provided because the country is a pioneer in smart grid technologies deployment in West Africa. In Section 6, the paper concludes that the integration of socio-economic aspects, regulatory aspects, financial aspects, and technical aspects in smart grid deployment is key to resolving West Africa's electricity dilemma. Last, the paper communicates the necessity for future work based on interviews with stakeholders of the West African electricity sector as a mean to verify the extent to which smart grid opportunities are realizable in the region and enrich what can be learned through secondary research with what can only be learned from those active on the ground.

2. West Africa electricity dilemma

Constraints triggering poor electricity access in West Africa are grouped under five aspects. Constraints pertaining to regulatory aspects are presented in section 2.1.. Section 2.2. presents electricity demand side constraints identified in economic and social aspects, while section 2.3. presents electricity supply side constraints identified in financial and technical aspects. All aspects and their associated constraints presented in the following sub-sections are identified in the literature as contributing directly or indirectly to widening the gap in electricity access across West Africa. Figure 1 nurtures its inspiration from the fishbone or Ishikawa diagram. It provides a visual illustration of constraints triggering poor electricity access in West Africa.

Figure 1. Poor electricity access causes diagram³

Sources: Author, (Yao , Sanogo , & Koutoua, 2014)

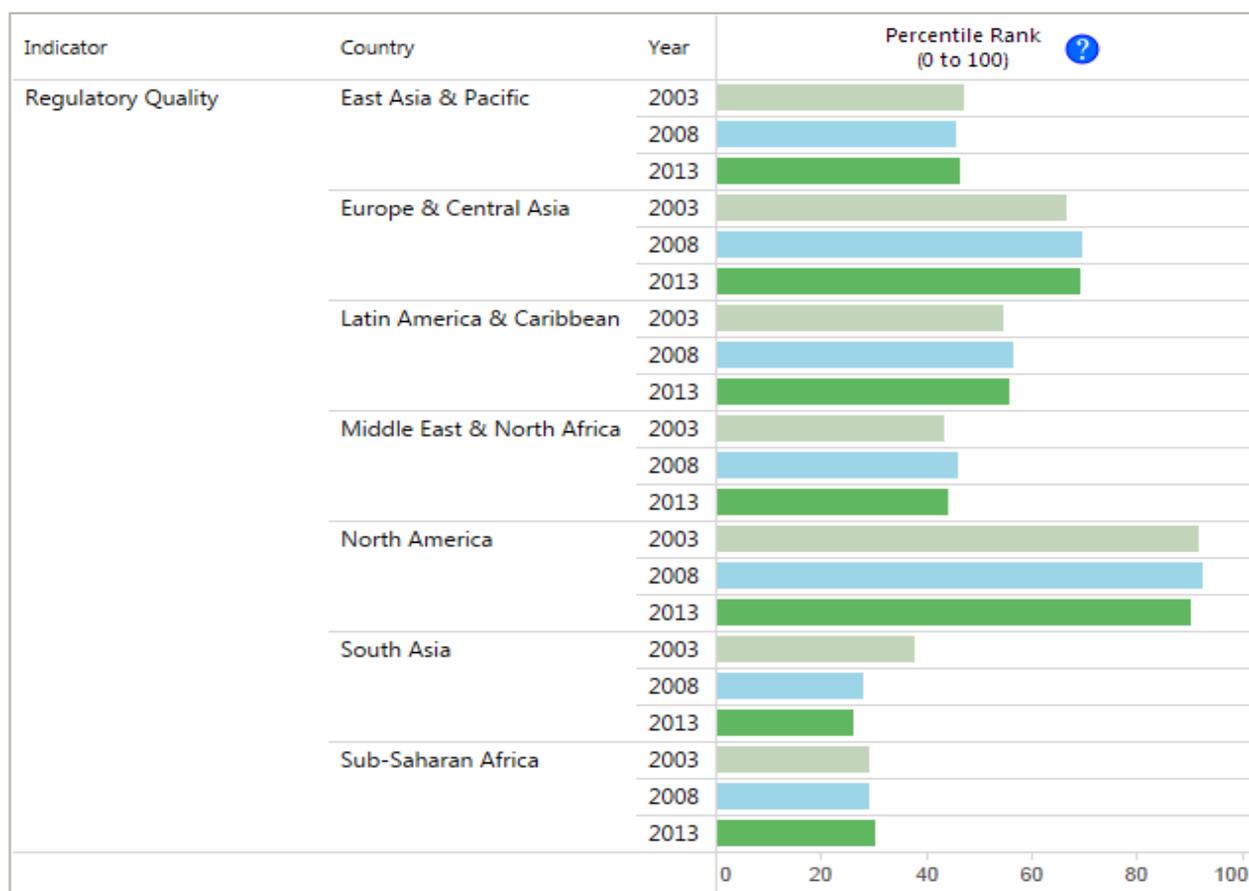
2.1. Regulatory aspects constraints

Weak regulatory frameworks in many African countries electricity sector are identified as constraints causing poor electricity access. According to Dahunsi, among unique challenges facing the energy sector in Africa we can record weak governance and regulatory frameworks at national and sub-regional level impeding the performance of the energy sector (Dahunsi, 2013). Figure 2 is constructed using the Worldwide Governance Indicators (WGI) that summarize perceptions on quality of governance of individual countries, geographical regions and income groups (Kaufmann, Kraay, & Mastruzzi, 2014). Figure 2 highlights sub-Saharan Africa percentiles ranking in terms of regulatory quality. From the chart, we notice that sub-Saharan Africa percentiles ranking is among the lowest worldwide and it has hardly improved. In 2003, sub-Saharan Africa regulatory quality ranked at the 28th percentiles and as of 2013 it

³ Constraints highlighted within each aspect were identified in the literature.

ranks at the 30th percentiles. Thus, in a ten year span, perceptions of sub-Saharan Africa regulatory quality have only increased by two percentiles.

Figure 2. World regional average percentile ranking of regulatory quality



Source: (Kaufmann, Kraay, & Mastruzzi, 2014)

Figure 3 provides a refined view of West African countries percentiles range position in 2013 in terms of regulatory quality. The map indicates that with the exception of Senegal and Ghana who both rank between the 50th and 75th percentiles, the remaining thirteen West African countries all rank below the 50th percentiles. Greater improvements must be realized to boost West African countries regulatory quality. As stressed by Thiam⁴ in (ERERA, ERERA CHAIRMAN SAYS GOOD GOVERNANCE, NEW MENTALITY ARE PANACEA TO ENERGY, 2014), West Africa needs to enforce good governance in the energy sector if the region is to successfully address its energy crisis.

⁴ El Hadj Ibrahima Thiam is Chairman of the ECOWAS Regional Electricity Regulatory Authority (ERERA).

Figure 3. West African countries percentile range of regulatory quality



Source: (Kaufmann, Kraay, & Mastruzzi, 2014)

Another constraint identified as contributing to poor electricity access in West Africa is the lack of policy incentives that are pro-energy efficiency. According to Fall⁵, the lack of incentives for substantial energy efficiency and the unclear position of some African governments for pursuing and fostering energy efficiency programs both hinder the penetration of energy efficiency tools (Fall, 2010), such as smart grid. Nevertheless, the establishment of the ECOWAS Regional Electricity Regulatory Authority (ERERA) is geared to challenge the status quo in the West African energy regulatory landscape by promoting regional electricity interconnection to overcome poor electricity access. Indeed, ERERA strives to establish appropriate legal and institutional frameworks for the development of the electricity sector in West Africa (ERERA, Welcome to ERERA, n.d.). Regional electricity interconnection and the extension of transmission infrastructures are an essential step toward facilitating the deployment of smart grid.

Thus, the creation of ERERA⁶ provides a potential solution to resolve current regulatory constraints such as weak regulatory frameworks and lack of pro-energy efficiency policy incentives. It will be particularly interesting to follow ERERA's growth and achievements in coming years. Further information on ERERA is provided in sub-section 4.2 which describes key roles and responsibilities in smart grid regulation that an organization such as ERERA could play.

⁵ Latsoucabe Fall is Africa Regional Manager at the World Energy Council.

⁶ The ECOWAS Regional Electricity Regulatory Authority (ERERA) was just created in 2008 and it is the regional regulator for cross-border electricity interconnections in West Africa.

2.2. Electricity demand side dilemma

This sub-section identifies constraints that contribute to poor access to electricity in West Africa. These constraints affect the electricity sector demand side from social and economic aspects. Social aspects constraints relate to non-technical losses/fraud, population growth and low rural electrification, while economic aspects constraints relate to lack of adequate research and development (R&D) structures, income growth and industrialization.

2.2.1. Social aspects constraints

Low rural electrification constitutes a major challenge toward reducing poor electricity access in West Africa. Presently, near 56% of the West African population lives in rural areas (UN Population Division, 2014). Given that this status is expected to decrease by 2050 with 37% of the West African population residing in rural areas, it is important to consider whether investments in transmission and distribution networks extension to rural areas is adequate when taking into account important local constraints such as dispersed rural population, low purchasing power, and limited potential for load growth (Kirubi, Jacobson, Kammen, & Mills, 2009). An option that could come to mind for rural electrification could be the extension of transmission networks across West Africa's rural areas. But, this option is financially not viable in terms of infrastructures extension because of long distances and difficult geographic terrain, which are prone to drive greater electricity losses (Kirubi, Jacobson, Kammen, & Mills, 2009). Welsch in (Welsch, Bazilian, Howells, & Divan, 2013) advocates the deployment of socially just power systems in sub-Saharan Africa as a mean to promote access to modern energy services without marginalizing the poor. Sub-section 4.1 introduces smart grid opportunity to overcome low rural electrification through the deployment of socially just grids such as off-grid systems in the form of small-scale renewable energy technologies (RETs).

The development of non-technical losses such as fraud constitute a major challenge to the electricity sector and most particularly to West African utilities. Fraud create constraints on electricity consumption (Kouassi, 2014) and hinder equitable distribution of electricity. Fraudulent electricity consumption can result from illegal connections to existing networks, tampering or bypassing with metering equipment or refusal to pay for service (PPPIRC, 2014). The deployment of smart grid technologies such as smart meters can help prevent non-technical losses. Sub-section 4.1 discusses smart grid opportunities provided through smart meters to alleviate non-technical losses.

As of 2013, West African household access to electricity services is about 40% in urban areas and 6% to 8% in rural areas (Saho, 2013). This situation is bound to worsen if no adequate measures are

adopted by the West African electricity sector to meet forthcoming electricity demand. In fact, electricity demand in most West African countries is expected to grow at an average annual rate ranging from 5% to 7% from 2010 to 2025 (WAPP, Business Plan 2012 - 2015, 2012) primarily due to urban population growth in most countries in the region.

Table 1. (%) Projected share of urban population per African regions, 1990-2050

Year	Central	East	North	South	West	Total
1990	32	18	46	49	30	36
2014	44	25	51	61	44	45
2050	61	44	63	74	63	61
Mini Chart						

Source: (UN Population Division, 2014)

Table 1 highlights various African regions' projected population growth and it includes the growth of urban population which is forecasted to represent 63% of the West African population by 2050 (UN Population Division, 2014). This exponential urban growth could create power supply shortages in the region if no proactive actions are taken to extend and improve transmission and distribution networks in cities and urban agglomerations. Hence, population growth represents a foreseeable constraint that originates from the electricity demand side with a strong propensity to widen electricity access gap in West Africa if the status quo in electricity infrastructures development prevails. Sub-section 4.1 discusses smart grid opportunities that can be leveraged to mitigate potential prospective unmet demand due to population growth.

2.2.2. Economic aspects constraints

Several experts of the West African electricity sector expressed in the literature that the lack of adequate R&D structures represent barriers to improving electricity access. For instance, Kakou⁷ affirmed during his intervention at the Africa Smart Grid Forum that sub-Saharan Africa did not dispose of adequate research and development (R&D) structures (Yao , Sanogo , & Koutoua, 2014). Moreover, in (Saho, 2013), Saho⁸ specifies that West Africa has limited R&D with little or no linkages to the entrepreneurial and manufacturing sectors. It is true that historically West African countries have been able to take advantage of technological advances for leapfrogging traditional power systems.

⁷ Dominique Kakou is CEO of the Electrical Company of Côte d'Ivoire (CIE).

⁸ Bah F.M. Saho is renewable energy expert.

Nevertheless, in order to master and adapt new technologies to the region and countries specific context, considerable investments should be pursued to create and strengthen R&D structures relationship with entrepreneurial and manufacturing sectors. Sub-section 4.1 introduces the African Smart Grid Research seminar, which was hosted in June 2014 at the Eskom Centre of Excellence at University of Kwazulu-Natal in South Africa (University of Kwazulu-Natal, n.d.).

Table 2 shows real per capita GDP growth from 2005 to 2015 in four sub-Saharan African regional economic groups, including the Economic Community of West African States (ECOWAS). Since 2005, income per capita levels have followed an upward trend overall. The International Renewable Energy Agency (IRENA) 2011 report on the *Prospects for the African Power Sector* introduces a demand modelling which assumes that in developing countries, electricity demand tends to grow at least as fast as GDP (IRENA, 2011). In fact, IRENA's demand model assumes that between now and 2030 electricity demand in West Africa will grow at the rate of GDP growth plus 1% (IRENA, 2011). Adapting IRENA's assumption to the International Monetary Fund (IMF) data on table 2, we should expect an electricity demand growth of at least 4.9% in West Africa for the year 2015. This growth in electricity demand as a result of a growth in GDP can be explained by the access to new technologies in urban areas such as household electronic goods.

Table 2. (%) Real per capita GDP growth 2005-2015

Year	CEMAC	COMESA	SADC	ECOWAS	Total
2005	1.5	4.3	4.7	2.4	3.2
2006	-0.7	4.1	5.3	2.6	2.8
2007	1.8	5.2	5.9	3.2	4.0
2008	2.1	3.8	3.5	3.0	3.1
2009	-1.6	2.4	-1.6	2.7	0.5
2010	3.4	4.4	2.3	4.2	3.6
2011	1.5	4.3	2.4	3.9	3.0
2012	2.8	3.2	1.9	3.9	3.0
2013	0.6	4.0	1.4	3.3	2.3
2014	3.4	3.9	2.0	3.9	3.3
2015	2.3	4.1	2.3	3.9	3.2
Mini Chart					

Source: (International Monetary Fund (IMF), 2014)

Given projections of an exponential growth in urban population representing 63% of the West African population by 2050 and considering sustained GDP growth, we may assume that there will be greater access to technologies by households. Again, if no proper measures are taken to increase the

supply of electricity and render it more efficient to meet the growing demand in urban areas, supply limitations will occur. Sub-section 4.1 discusses smart grid opportunities that can be leveraged to meet increasing electricity demand triggered by income growth.

In some West African countries, electricity demand growth will be more driven by the need to meet production output due to industrialization concomitantly to population and income growth. For instance, Nigeria predicts an annual growth rate in electricity demand from 2010 to 2025 of more than 8% in order to meet its huge electricity deficit, while in the same timeframe Guinea predicts an annual growth rate in electricity demand of 14% due to the significant development of smelting industries in the country (WAPP, Business Plan 2012 - 2015, 2012). Sub-section 2.3. introduces a set of constraints instigated from the electricity supply side which also contribute to poor access to electricity in West Africa.

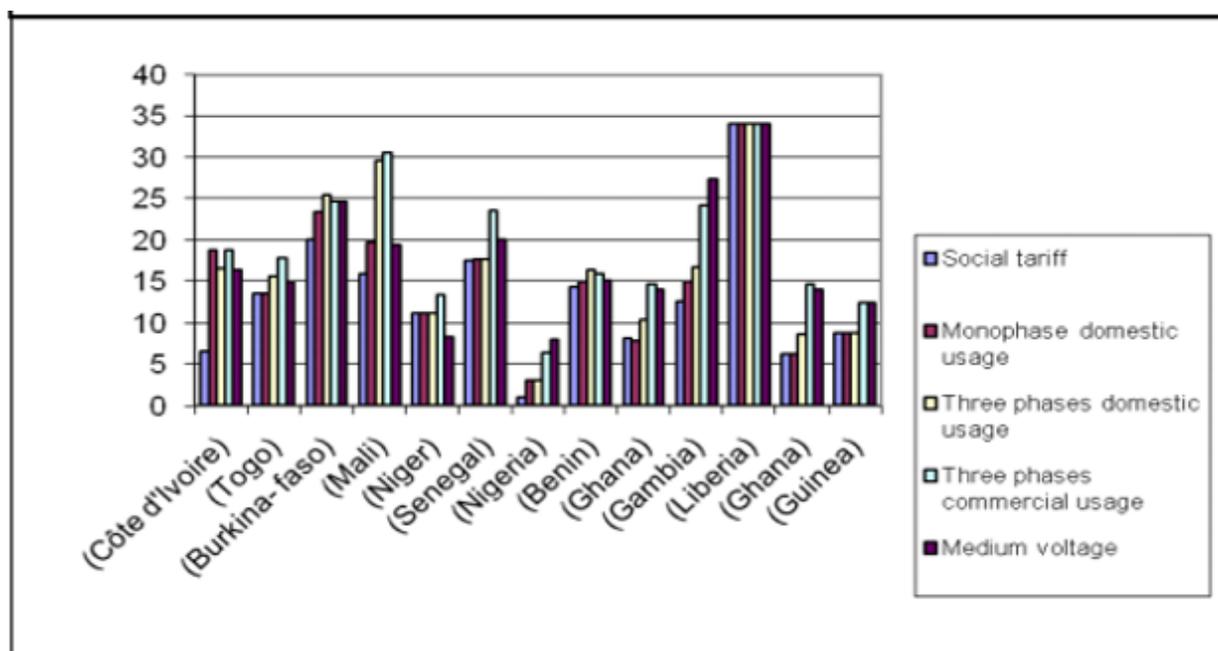
2.3. Electricity supply side dilemma

In this section, constraints contributing to widening electricity access gap arise from two aspects: Financial aspects and technical aspects. Financial aspects constraints relate to high electricity costs and lack of adequate financing, while technical aspects constraints are tied to inadequate generation and transmission & distribution capacity/losses.

2.3.1. Financial aspects constraints

Due to limited access to the most recent comparative electricity tariffs charged by West African utilities in the ECOWAS region, this paper uses 2011 data shared in the Infrastructure Consortium for Africa (ICA) report on *Regional Power Status in African Power Pools*. High electricity costs in Africa still constitute one of the major challenges faced by the electricity sector (Manz, D, 2011). In West Africa, electricity is produced and distributed at high costs and this cost is transferred to consumers taking the form of high electricity tariffs. In (Infrastructure Consortium for Africa (ICA), 2011), it is explained that *“tariffs are often not reflecting the real cost of generation, transmission and distribution. The final consumer is in some cases also paying the cost of self-generation and the cost of service disruption.”* High tariffs of electricity mainly impacts poor segments of the West African population (Dahunsi, 2013) who suffer the most when power outages occur and who face additional financial constraints to pay electricity bills.

Figure 4. WAPP 2009 electricity tariffs per member countries (cUS\$/KWh)



Source: (Infrastructure Consortium for Africa (ICA), 2011)

Figure 4 highlights various electricity tariffs based on consumer categories across West African countries. According to (Infrastructure Consortium for Africa (ICA), 2011), electricity tariffs are a set of various tariffs related to the consumer profile/category. Social tariff relate to the lowest electricity consumption of 100 KWh/month, single phase domestic usage relates to 2KW, three phases commercial usage refers to 12 KW, and medium voltage corresponds to 35000 KWh/month (Infrastructure Consortium for Africa (ICA), 2011). For instance, in West African Power Pool (WAPP) member countries, social tariffs vary from a very low level of 1.05 cents US\$/KWh in Nigeria to a maximum of 34 cents US\$/KWh in Liberia, as compared to an average social tariff of 13 cents US\$/kWh for the region. A smart grid solution that could mitigate high electricity costs is the usage of smart meters to leverage demand response programs such as the empowerment of electricity consumers to decrease consumption in response to changes in price. Sub-section 4.3 defines and introduces demand response opportunities for West Africa.

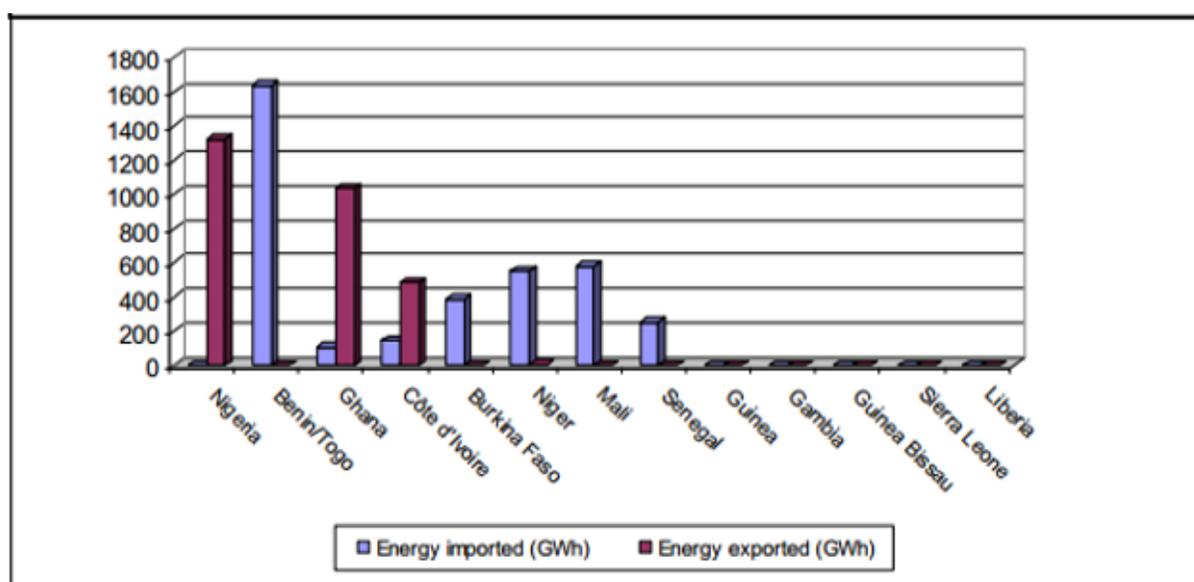
The lack of adequate financing of electric utilities is another supply side constraint in regard to West Africa's electricity dilemma. There is a low regional self-financing capacity in terms of electric infrastructures. Significant financing requirements need to be mobilized but they are not met (WAPP, Business Plan 2012 - 2015, 2012). Moreover, there is a lack of financial incentives to boost private sectors investments in electric infrastructures development. West African regional power integration

initiatives should be enhanced to find diversified and viable financing strategies as further exposure to the world financial crisis could reduce institutional donors flow of financing to developing countries, hence affecting the region's financial ability to unleash projects aimed at resolving poor electricity access. Sub-section 4.3 relays financing opportunities such as the development of metered-based tariffs and prepayments via mobile phones to help customers monitor consumption and reduce high electricity costs.

2.3.2. Technical aspects constraints

Inadequate generation is one of the most recurrent technical constraints that is continuously mentioned in the literature concerning West Africa's electricity dilemma. A high level of performance deficiencies is noted in the electrical sector because of insufficient generation infrastructures in virtually all countries within West Africa (WAPP, Business Plan 2012 - 2015, 2012). Moreover, energy crises resulting in the rise of petroleum products price hinder activities of some utilities in the region that rely on fuel supplies to operate their power plant (WAPP, Business Plan 2012 - 2015, 2012).

Figure 5. WAPP 2010 energy imports & exports per country (GWh)



Source: (Infrastructure Consortium for Africa (ICA), 2011)

Figure 5 shows that West African countries with the exception of Nigeria, Ghana and Côte d'Ivoire significantly import more energy than they export. In 2009, energy imports increased by 45% in Benin and Togo combined, 15.9% in Mali, 15% in Niger, 10.5% in Burkina Faso, 6.9% in Senegal, 3.9% in Côte d'Ivoire, and 2.9% in Ghana (Infrastructure Consortium for Africa (ICA), 2011).

Table 3. WAPP region power generation variance analysis

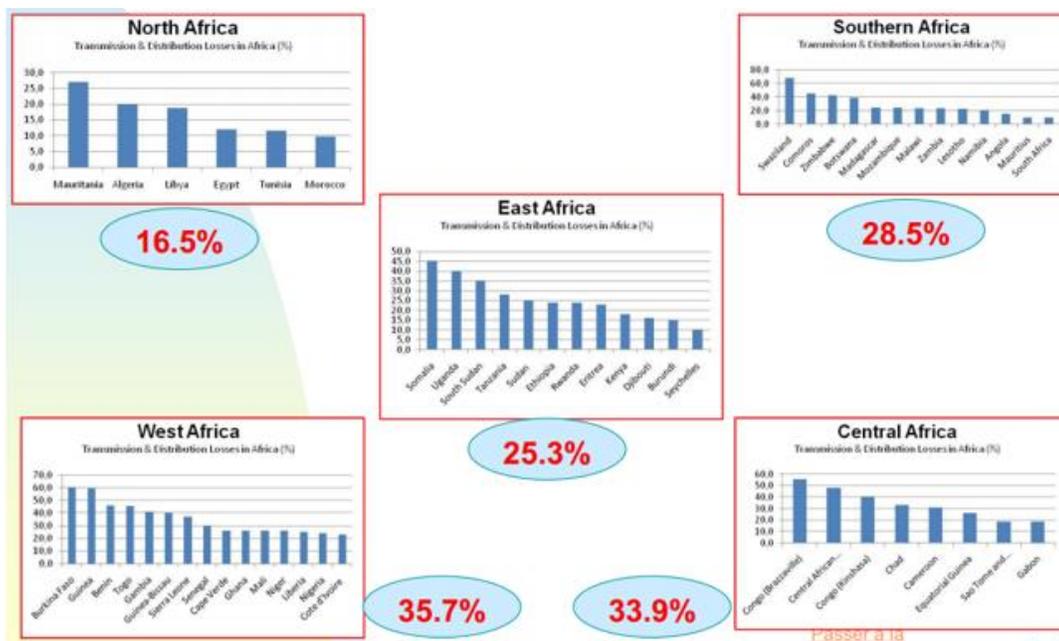
Scenario/Year	2009	2010	2011
Actual Amount in GWh	41,000	48,500	50,000
Planned Amount in GWh	64,070	68,076	72,275
Over(under) Generated in GWh	(23,070)	(19,576)	(22,275)

Source: (WAPP, Business Plan 2012 - 2015, 2012)

Table 3 highlights shortages in electricity supply in West Africa during periods 2009, 2010, and 2011. These shortages were due to droughts and non-availability of gas, which respectively led to insufficient electricity generation from hydropower and thermal sources. These environmental constraints spurred energy imports in West Africa during that period. The integration of distributed generation in the form of renewable energy sources to the power grid could help palliate generation deficiencies. Sub-section 4.4 discusses smart grid deployment opportunities offered through distributed generation to resolve the West African electricity dilemma.

Electricity access is far from benefiting the majority of West Africans due to insufficient transmission and distribution infrastructures (WAPP, Business Plan 2012 - 2015, 2012). These infrastructures need to be extended in order to reach populated areas that are under-served and disconnected from the grid. Constraints facing transmission and distribution networks relate to high losses, long feeders, voltage fluctuations and cable overloads, among other (Manz, D, 2011).

Figure 6. Power transmission & distribution losses percentages per African region



Source: (Elhag, 2014)

Figure 6 depicts the power transmission and distribution (T&D) losses percentage per region in Africa. With T&D losses of 35.7%, West Africa exhibits the highest rate in the continent and it is more than triple the international accepted norm of 10% (Elhag, 2014). Meanwhile, growth rates in Africa from 2011 to 2016 are expected to average 10.7% for transmission losses and 11.5% for distribution losses (Elhag, 2014). The necessity to upgrade the transmission and distribution networks in West Africa is pressing and imminent. ERERA and WAPP are taking significant measures to ensure the promotion and development of power generation and transmission facilities across West Africa. Various investments targeting the integration of West African national power systems have been and are undertaken. For instance, below is a list of some on-going priority projects led by WAPP:

- 330 KV Volta (Ghana) – Lome C (Togo) – Skalette (Benin) Interconnection Project
- 330 KV TCN (Nigeria) – CEB (Benin) Interconnection Reinforcement Project
- 225 KV Ghana – Burkina – Mali Interconnection Project
- 225 KV Guinea – Mali Interconnection Project
- 339 KV Aboadze – Prestea – Kumasi – Bolgatanga & 161 KV Tumu – Han – Wa Transmission Line Projects

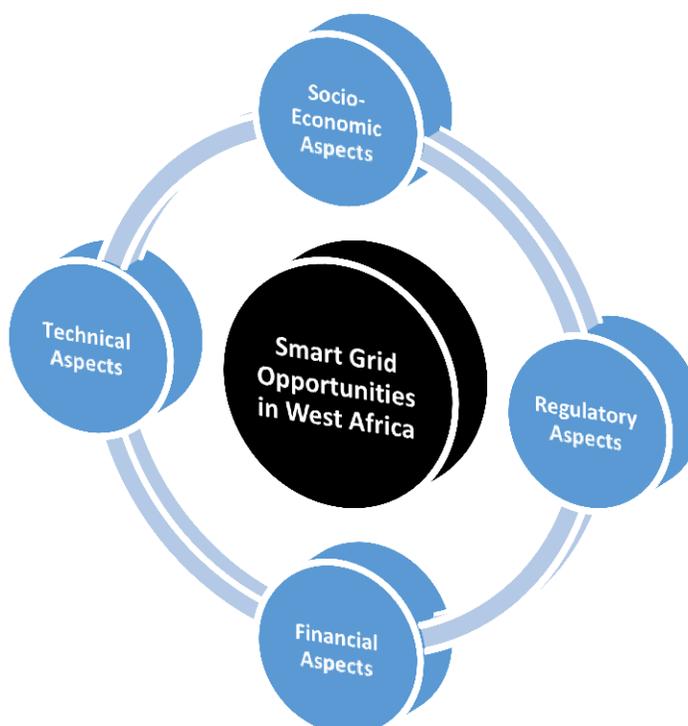
Although access to energy is not be the primary need that humans seek to fulfill, “access to modern forms of energy is essential for the provision of clean water, sanitation and healthcare and provides great benefits to development through the provision of reliable and efficient lighting, heating, cooking,

mechanical power, transport and telecommunications services” (International Energy Agency, 2010). Resolving the electricity sector demand and supply side constraints, as well as regulatory constraints are prerequisites if West Africa intends to march toward the path of development.

3. Conceptual framework

The conclusion of keynote presentations at the first Africa Smart Grid Forum strongly emphasized the importance of integrating regulatory aspects, financial aspects, and technical aspects to avoid the failure of smart grid deployment (Yao , Sanogo , & Koutoua, 2014). It is important to integrate these three aspects to ensure the successful deployment of smart grid. Nevertheless, an intrinsic element -- socio-economic aspects-- was not adequately emphasized in the smart grid deployment framework drew from the Africa Smart Grid Forum 2014 keynote presentations. Any initiative supporting the deployment of smart grid technologies should integrate consumers represented by the civil society and consumer groups alongside the interests of businesses, governments and the electricity sector. Henceforth, socio-economic aspects are added to the three aspects discussed at the Africa Smart Grid Forum 2014 to complete the research conceptual framework which is visually presented in figure 7.

Figure 7. Conceptual framework



Sources: Author, (Yao , Sanogo , & Koutoua, 2014)

4. Smart grid opportunities for West Africa

Smart grid is proposed as an option to resolve the electricity dilemma in West Africa because it is the future of electrical systems. Smart grid is designed to fulfill four major electricity requirements in terms of capacity, reliability, efficiency, and sustainability (Elhag, 2014). According to Elhag, smart grid meets four major electricity requirements by fulfilling growing demand of electrical energy, providing high-quality electrical energy whenever it is needed, increasing the efficiency of power generation and reducing losses in transmission, distribution and consumption of electrical energy, and last by ensuring the effective integration of renewable power generation (Elhag, 2014). Furthermore, smart grid deployment is inevitable for developing countries in the future because it offers energy management features via the use of telecommunications⁹ and the integration of renewable energy to the grid (Fadaeenejad, et al., 2014). In sub-section 4.1, the paper introduces West Africa smart grid opportunities that could help resolve socio-economic constraints discussed in sub-section 2.2. Sub-section 4.2 presents ERERA, as well as roles and responsibilities in smart grid regulation. Sub-section 4.3 introduces smart grid opportunities that can alleviate financial constraints discussed in sub-section 2.3. Last, sub-section 4.4 discusses the role of distributed generation to overcome technical constraints.

4.1. Socio-economic aspects opportunities

In sub-section 2.2 we learned that non-technical losses/fraud, population growth, low rural electrification, high electricity costs, lack of adequate financing, inadequate generation, and transmission & distribution capacity/losses contribute to poor access to electricity in West Africa. This part introduces smart grid opportunities that can benefit West Africa and help resolve socio-economic constraints discussed in sub-section 2.2.

Prior to introducing findings, it is important to emphasize that prospective electricity consumers' social and economic contexts should be considered and their voices should be heard in the smart grid deployment process. At the end, the customer is the primary cost bearer of supplied electricity.

Electricity consumers' primary experience with smart grid will be smart meters¹⁰. Successful diffusion of the technology will require to adapt smart meters functionalities to consumers' specific needs and means given specific social, economic and geographic contexts. Smart meters have the

⁹ "Any transmission, emission, or reception of signs, signals, writing, images and sounds or intelligence of any nature by wire, radio, optical or other electromagnetic systems." (TIA Glossary of Telecommunication Terms, n.d.).

¹⁰ "Smart Meters are electronic measurement devices used by utilities to communicate information for billing customers and operating their electric systems" (EEI, 2011).

potential to alleviate non-technical losses and electricity supply shortages triggered by increasing electricity demand due to population growth, income growth and industrialization. In (Kouassi, 2014), Kouassi explains that non-technical losses in the form of electricity theft have enticed Côte d'Ivoire's public utility to invest in the deployment of smart meters, which were adapted to the utility's specifications in order to help detect and prevent fraud.

In order to mitigate electricity supply shortages due to increasing demand it will be fundamental to adopt smart grid features that render the power grid more efficient. Such features are described by Welsch in (Welsch, Bazilian, Howells, & Divan, 2013) and they are wide-area monitoring and control, and distribution automation technologies. According to Welsch, the deployment of wide-area monitoring and control can better monitor disturbances within transmission networks by supporting accurate information required for real time decision making. From distribution networks standpoint, the deployment at critical points of distribution automation technologies such as smart sensors, flexible and intelligent switches and interrupters could minimize the extent of outages and increase the speed of restoration (Welsch, Bazilian, Howells, & Divan, 2013). Thus, the deployment of smart grid technologies such as smart meters, wide-area monitoring and control and distribution automation technologies can help alleviate non-technical losses and electricity supply shortages triggered by increasing electricity demand.

Furthermore, the pursuit for smart grid opportunities in West Africa should take into consideration the framework of "smart and just grid" proposed by Welsch emphasizing the need for African power system development to be also driven to benefit the poor, contributing toward equitable and inclusive economic and social development (Welsch, Bazilian, Howells, & Divan, 2013). In order to overcome low rural electrification, Alhborg in (Alhborg & Hammar, 2014) explains that off-grid electrification such as small decentralized electric grids or autonomous generation are adequate means of supplying electricity to remote areas in order to avoid investing in expensive transmission. One type of off-grid system that should be further considered and deployed in rural areas of West Africa are small-scale renewable energy technologies (RETs). The potential for RET-based electrification is high in sub-Saharan Africa in terms of hydropower and solar photovoltaic (PV) (Alhborg & Hammar, 2014). Several initiatives were executed by various entities in order to deploy small-scales PV in rural areas across Africa. The most recent and mediatized initiative is Akon¹¹ *Lighting Africa Project*. "*Akon, in partnership with Give1Project and ADS Global Corporation SA, has initiated the project "Akon Lighting Africa Project" tour which aims to bring electricity to one (1) million households in Africa by the end of 2014*" (Akon Lighting Africa

¹¹ Akon is a Senegal native and an American R&B and hip hop recording artist, songwriter and record producer.

Project, n.d.). According to (Akon Lighting Africa Project, n.d.), this project consists of the installation of solar equipment in households and the promotion of energy sufficiency in rural areas. So far, installations of solar equipment were completed in nine African countries: Senegal, Mali, Guinea Conakry, Gambia, Burkina Faso, Equatorial Guinea, Gabon, Congo and the Ivory Coast. It appears that in order to alleviate low rural electrification, off-grid systems may be a more viable option particularly in remote locations (Ahlborg & Hammar, 2014).

In sub-section 2.2 we also learned that the lack of adequate R&D structures is identified as a constraint contributing to the electricity dilemma. In order to improve R&D in Africa, in June 2014, Eskom¹² Centre of Excellence (COE) at University of Kwazulu-Natal in South Africa hosted the African Smart Grid Research seminar. According to (University of Kwazulu-Natal, n.d.) “the Smart Grid Research Laboratory is first of its kind in Africa for training and research development (modelling, simulation and real-time analysis) of Smart Technologies and the integration of various renewable energy technologies into the Grid.” The development of an R&D institution such as Eskom in West Africa could have a significant impact in innovation of smart grid technologies for the West African context.

4.2. Regulatory aspects opportunities

Cognizant of the importance of setting up a regional institutional regulatory organization with adequate policy framework to help solve West Africa’s electricity dilemma, the ECOWAS Regional Electricity Regulatory Authority (ERERA) was created. In 2008, by the supplementary Act A/sa.2/1/08, the ERERA was established with the mission to regulate cross-border electricity connections and trading among ECOWAS member States. The ERERA regulatory responsibilities include (i) the establishment of transparent tariff setting methodology for regional power pooling¹³; (ii) adopting technical regulation; (iii) monitoring of regional market operations; (iv) resolving disputes among regional market participants; (v) contributing to the development of regional energy policy and (vi) assisting in building capacity of national regulatory bodies (Infrastructure Consortium for Africa (ICA), 2011). From sub-section 2.1., we learned that the creation of ERERA provides a potential solution to resolve current

¹² “The Eskom Centre of Excellence (CoE) at UKZN also serves as the Eskom Power Plant Engineering Institute (EPPEI) Specialization Centre in High Voltage Direct Current (HVDC) Engineering. It is a multi-disciplinary research centre which focuses on research in technology relating to HVDC, power systems (including lines) and power electronics relating to alternate current systems. The Centre engages in applied scientific research and technology development in support of the National Development Plan (NDP) of the South African government, and to improve the living standards of people in the South African society and to contribute towards nation building” (University of Kwazulu-Natal, n.d.).

¹³ According to U.S. Energy Information Administration, a power pool is “an association of two or more interconnected electric systems having an agreement to coordinate operations and planning for improved reliability and efficiencies” (U.S. Energy Information Administration, n.d.).

regulatory constraints such as weak regulatory frameworks and lack of pro-energy efficiency policy incentives. Through the establishment of EREDA, ECOWAS created a platform on which policy framework can be developed to accompany the potential deployment of smart grid with adequate investments.

Concerning definitions of roles in smart grid regulation, from a competition standpoint one important responsibility of smart grid regulation will be to ensure non-discriminatory access of new entrants to smart meter and metering data (Kranz & Picot, 2013). Smart grid regulation should facilitate innovative services' emergence and consider implications for practitioners and regulators (Kranz & Picot, 2013). From a consumer perspective, smart grid regulation will have to develop robust data privacy and security policies in order to facilitate consumers' acceptance of smart grid technologies and services (Coney, 2013). As put by Lillie Coney in "Broadband Networks and Smart Grid: How Do We Build a Better Tomorrow?," *"innovation without consideration of consumer privacy in a digital information economy is a system that will have many dead ends before it can find a smooth path to success"* (Coney, 2013). In terms of smart grid regulation in West Africa, EREDA will have to fulfill roles and responsibilities described above in order to provide an adequate environment facilitating smart grid technologies deployment.

4.3. Financial aspects opportunities

The lack of adequate financing and high electricity costs are identified in the literature as impacting poor electricity access. From a financing standpoint, the scale required to enhance today's grid to meet the demand of future power systems is considerable and the associated monetary implications do not seem to be understood fully (Welsch, Bazilian, Howells, & Divan, 2013). This will pose a great budgetary equation for the West African region considering its reliance on international donors and its need to find supplemental funds to finance smart grid deployment in addition to funding already allocated for priority projects, establishment of regional electricity market, training programs, and operating budget of WAPP secretariat. According to WAPP, *"an evaluation of the implementation of the 2009 – 2012 WAPP Business Plan has indicated that 83% of the Priority Objectives that were outlined were achieved... Key among challenges encountered that affected the pace of implementation of the priority projects were delays in securing funding and the socio-political situations witnessed in the sub-region"* (WAPP, Business Plan 2012 - 2015, 2012).

Table 4. Business plan 2012-2015 summary budget ('000 US\$)

OBJECTIVES	ACTIVITIES	2013-2015	% of 2013-2015 Total	2013	2014	2015	Mini Chart
Priority Projects	WAPP	2,238	0.1%	971	781	486	
	Donors	3,872,771	99.9%	350,836	1,217,701	2,304,234	
	Utilities	2,300	0.1%	1,586	714	-	
	Total	3,877,309	100%	353,393	1,219,196	2,304,720	

Source: (WAPP, Business Plan 2012 - 2015, 2012)

Table 4 shows the West African Power Pool (WAPP) summary budget for the period covering 2013 to 2015. For the period 2013-2015, 99.9% of donors' share in funding priority projects are primarily related to power pool interconnections accounts. The weight of WAPP and member countries utilities funding is decreasing exponentially during the period, whereas donors' funding is following the opposite pattern. This situation calls for more research on opportunities in West Africa to leverage alternative financing options, such as public-private partnership (PPP) financing.

In order for West African electricity consumers to adjust consumption and reduce high electricity costs, further development of metered-based tariffs and prepayments via mobile phones seem to be viable and adequate options. Welsch highlights that *"meter-based tariffs incentivize an efficient use of electricity, which could result in considerable load reduction. A basic time-of-use pricing scheme at household level may easily be introduced in sub-Saharan Africa to help balance demand"* (Welsch, Bazilian, Howells, & Divan, 2013). Prepayment of electric bills in West Africa can either occur at cashiers or it can be leveraged through telecommunications and more particularly with the use of mobile phone. Prepayment via mobile phones could relieve consumers from pressure of covering past due bills, it allows them to better monitor and control consumption and it reduces long payment lines in front of cashiers (Kouassi, 2014). On utilities side, offering the option of prepayment of electric bills eliminates the risk of late payments and receivables from consumers (Kouassi, 2014).

Figure 8. Sub-Saharan Africa: percentages of mobile phones used to pay bills, 2011

Regarding transmission and distribution losses, adaptive voltage control at substations and line drop compensation to adjust feeder voltages are some smart grid features that could help minimize technical losses in transmission (Welsch, Bazilian, Howells, & Divan, 2013). However, successful smart grid introduction in the region is contingent to the improvement of current transmission and distribution infrastructures (Elhag, 2014). It seems that most African regional economic groups have understood the stakes in upgrading transmission and distribution infrastructures of power grid in order to render more efficient, reliable and accessible the distribution of electricity. As a result, regional power pools such as WAPP for West Africa have burgeoned across the continent to enhance interconnection of transmission and distribution networks.

In the context of West Africa, WAPP interconnection projects are contributing to the standardization of power system infrastructures, paving the way to leverage smart grid ICT features integration. Interoperability between features of smart grid, such as distributed generation, energy storage, demand response, micro grids, or home automation, will play a fundamental role in the successful operation of a networked, automated, distributed, market- and service-promoting ICT-enhanced energy system (Noam, Pupillo, & Kranz, 2013). There is an increasing nexus between telecommunications and electricity as communications and computing are increasingly dependent on reliable and high-quality power, while the efficient and reliable distribution of power is increasingly dependent on communications and computing (Patel & Taneja, 2014). The two-way flow of electricity and information to provide superior performance to customers at lower costs is facilitated through the use of broadband networks, sensors, smart meters, and software (Noam, Pupillo, & Kranz, 2013). For now, the future of broadband development seems promising for West African customers given that broadband prices continue to tumble as operators try to find the price point (Balancing Act, 2009).

5. Smart grid technologies deployment in Côte d'Ivoire

Section 5 provides information on smart grid deployment in Côte d'Ivoire, a member country of ECOWAS and WAPP. It presents smart meters installation pilot project and the deployment of power line communication (PLC)¹⁴ in Côte d'Ivoire.

¹⁴ “Power line communications (PLC) make it possible to transmit digital and voice data through electric cables. Subscribers access broadband services (telephone, internet, CCTV) from basic wall sockets” (Eranove, n.d.).

Côte d'Ivoire is a pioneer in the adoption of smart grid in Africa. The country's public utility, Compagnie Ivoirienne d'électricité (CIE), is committed to resolve its electricity dilemma through the deployment of smart grid which will allow for better exploitation of electric networks through the integration of distributed generation with renewable energy and the setup of new services to electricity customers via information communications technologies (ICT) (Kouassi, 2014).

Since March 2014, CIE launched a pilot project for the installation of 250 smart meters in a group of newly electrified villages located in Didievi¹⁵ (Kouassi, 2014). As of the partial project evaluation in May 2014, CIE deemed that smart meters operation results were satisfactory (Kouassi, 2014). The dissemination of smart meters were accepted by rural populations involved in the pilot project (Kouassi, 2014). Moreover, the technology relieved CIE technical staff from physically being present in front of the metering device to read and record electricity consumption (Kouassi, 2014).

The launch of smart meters pilot project in Didievi is not the first initiative realized by CIE and the government to deploy smart grid technologies in the country. Indeed, in 2010, a contract was signed between the authorities of Côte d'Ivoire and the company Awale¹⁶ (All West African Linked by Energy) to build and operate an optical fiber¹⁷ and power line communication (PLC). According to Eranove's report on Awale, *"operations began in July 2013 and cater to a strong demand from cell phone operators and Internet providers (growth in the number of 3G and Internet connections in Côte d'Ivoire)"* (Eranove, n.d.). One feature attracting telecommunications operator to use PLC is that there is no risk of vandalism using PLC compared to frequent thefts of telephone cables for their copper content (Eranove, n.d.). The deployment of smart grid technologies such as PLC proves that there is a telecommunications and electricity nexus where both sectors can benefit from the deployment of this smart grid technology, contributing to enhancing quality of services and access.

6. Conclusion and future study

In West Africa, the electricity dilemma refers to poor electricity access given that only 30% of the West African population has access to power supply (WAPP, Business Plan 2012 - 2015, 2012). This results from an amalgamation of constraints emanating from the regulatory environment, the demand and supply side of the electricity sector. These constraints relate to weak regulatory frameworks, lack of pro-energy efficiency policies, non-technical losses/fraud, population growth, low rural electrification,

¹⁵ Didievi is a commune in Côte d'Ivoire.

¹⁶ "Awale's activity consists in installing the PLC communication equipment on the electricity distribution switchgear, and to rent out PLC lines to professionals by 1000 or 10,000 line batch (telco operators, Internet providers, infrastructure leasing, businesses for their internal needs)" (Eranove, n.d.).

¹⁷ "Optical fibre is installed on high voltage power lines for data transmission" (Eranove, n.d.).

high electricity costs, lack of adequate financing, lack of adequate financing, inadequate generation and transmission & distribution capacity/losses. Smart grid deployment in West Africa is identified by African experts of the electric sector as a solution or as some believe it *the* solution to resolve the electricity dilemma. The smart grid technology deployment path will vary at regional and country levels due to diverse needs and goals of different societies and markets (Welsch, Bazilian, Howells, & Divan, 2013). The deployment of smart grid -- if integrating socio-economic aspects, regulatory aspects, financial aspects, and technical aspects-- can help resolve the electricity dilemma in West Africa. Successful smart grid deployment in West Africa could save significant amount of lost power supply to feed unconnected customers (Elhag, 2014). As we learned in the case of Côte d'Ivoire, a pioneer in smart grid technologies deployment in West Africa, telecommunications will play a key role in leveraging the benefits of smart grid from a demand management perspective and given the future of electric distribution which is computerized and data-driven (Elhag, 2014). Smart grid deployment is an absolute and pressing necessity for Africa because if nothing is done, as stated by Claude Koutoua¹⁸, "*we will end up with obsolete equipment and without the possibility of providing operating and maintenance tasks*" (WAPP, Business Plan 2012 - 2015, 2012).

The next stage of research in this area will involve interviews with stakeholders of the West African electricity sector in order to further explore the extent to which smart grid opportunities are realizable in West Africa and evaluate the utility of what has been learned from the literature in light of contemporary realities on the ground.

References

- Ahlborg, H., & Hammar, L. (2014). Drivers and Barriers to Rural Electrification in Tanzania and Mozambique - Grid-Extension, Off-Grid, and Renewable Energy Technologies. *EISEVIER*, 61, 117-124.
- Akon Lighting Africa Project. (n.d.). *About*. Retrieved 10 24, 2014, from <http://www.akonlightingafrica.com/hideakone/index.php/about>

¹⁸ President of the African Electrotechnical Standardization Commission (AFSEC).

- Balancing Act. (2009). *West African consumer broadband prices continue to tumble as OTI Telecom lowers its retail offer - See more at: <http://www.balancingact-africa.com/news/en/issue-no-418/top-story/west-african-consume/en#sthash.jNRGRGOT.dpuf>*. Retrieved from balancing act: <http://www.balancingact-africa.com/news/en/issue-no-418/top-story/west-african-consume/en>
- Balijepalli, M. V., Pradhan, V., Khaparde, A. S., & Shereef, M. R. (2011). Review of Demand Response Under Smart Grid Paradigm. *Innovative Smart Grid Technologies - India (ISGT India), 2011 IEEE PES*, (pp. 236-243). Kollam, Kerala. doi:10.1109/ISET-India.2011.6145388
- Coney, L. (2013). Broadband Networks and Smart Grid: How Do We Build a Better Tomorrow? In E. M. Noam, M. L. Pupillo, & J. J. Kranz, *Broadband Networks, Smart Grids and Climate Change* (pp. 175-191). New York: Springer Science+Business Media.
- Dahunsi, F. M. (2013). Conceptual Framework for Sustainable Energy Development in Africa. *Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON), 2013 IEEE International Conference on* (pp. 238-241). Owerri: IEEE. doi:10.1109/NIGERCON.2013.6715661
- EI. (2011). *Smart Meters and Smart Meter Systems: A Metering Industry Perspective*. Washington: Edison Electric Institute. Retrieved from <http://www.eei.org/issuesandpolicy/grid-enhancements/Documents/smartmeters.pdf>
- Elhag, H. (2014, May 14-16). Future of Smart Grid in Africa: Making Sky Image of Africa More Brighter. Abidjan, Lagunes, Côte d'Ivoire.
- Eranove. (n.d.). *Awale*. (Eranove) Retrieved 10 24, 2014, from <http://www.eranove.com/en/our-companies/francais-awale/>
- ERERA. (2014, July 14). *ECOWAS ENERGY INSTITUTIONS HOLD COORDINATION MEETING IN ACCRA*. Accra: Department of Communication of ECOWAS Regional Electricity Regulatory Authority. Retrieved 10 20, 2014, from <http://www.erera.arrec.org/getattachment/ad1fa2f5-f4b4-4b93-893b-ba010c860f7b/Documents/List/English/PR---EECOWAS-ENERGY-INSTITUTIONS-HOLD-TALKS-IN-ACC.aspx>
- ERERA. (2014, 5 29). *ERERA CHAIRMAN SAYS GOOD GOVERNANCE, NEW MENTALITY ARE PANACEA TO ENERGY*. Accra: Department of Communication of ECOWAS Regional Electricity Regulatory Authority. Retrieved 10 20, 2014, from <http://www.erera.arrec.org/getattachment/fd81f84a-8ebd-4a0e-bd65-9b2ea18550c4/Documents/List/English/PR---ERERA,-WAPP-ELABORATE-ENERGY-PROGRAMMES-ON-EC.aspx>

- ERERA. (2014). *ERERA, KfW HOLD TALKS ON 330KV GHANA-COTE D'IVOIRE INTERCONNECTION LINE*. Accra: Department of Communication of ECOWAS Regional Electricity Regulatory Authority. Retrieved 10 20, 2014, from <http://www.erera.arrec.org/getattachment/25c800f5-84ce-4018-a936-b5ccf72ac517/Documents/List/English/PR---ERERA,-KfW-to-Deepen-Cooperation.aspx>
- ERERA. (n.d.). *Welcome to ERERA*. (ERERA) Retrieved 10 15, 2014, from <http://www.erera.arrec.org/>
- Fadaeenejad, M., Fadaee, M., Radzi, M. A., Hizam, H., AbKadir, M. Z., & Saberian, A. M. (2014). The Present and Future of Smart Power Grid in Developing Countries. *Renewable & Sustainable Energy Reviews, 29*, 828-834.
- Fall, L. (2010, September 12-16). *Achieving Energy Efficiency in Africa: What are the Priorities, the Best Practices and the Policy Measures*. Montreal, Quebec, Canada.
- Ibrahima, T. F. (2013). *Improving Access Through Regional Electricity Infrastructure Projects*. ERERA. Banjul. Retrieved 10 20, 2014, from http://www.erera.arrec.org/getattachment/f46a7306-2dc3-4f7a-a225-4eb2e569a1fc/Documents/List/English/Session-2_2-Expose.aspx
- Infrastructure Consortium for Africa (ICA). (2011). *Regional Power Status in African Power Pools*. Tunis: Infrastructure Consortium for Africa (ICA). Retrieved from http://www.icafrica.org/fileadmin/documents/Knowledge/Energy/ICA_RegionalPowerPools_Report.pdf
- International Energy Agency. (2010). *Energy Poverty: How to Make Modern Energy Access Universal*. Paris: International Energy Agency. Retrieved from http://www.worldenergyoutlook.org/media/weowebiste/energydevelopment/weo2010_poverty.pdf
- International Monetary Fund (IMF). (2014, April). *Sub-Saharan Africa Fostering Durable and Inclusive Growth*. Washington, DC, USA. Retrieved from <http://www.imf.org/external/pubs/ft/reo/2014/afr/eng/sreo0414.pdf>
- IRENA. (2011, December 4). *Prospects for the African Power Sector*. Durban, Abu Dhabi, KwaZulu-Natal. Retrieved from http://www.irena.org/DocumentDownloads/Publications/Prospects_for_the_African_PowerSector.pdf
- Kaufmann, D., Kraay, A., & Mastruzzi, M. (2014). *Worldwide Governance Indicators*. (The World Bank Group) Retrieved 10 15, 2014, from <http://info.worldbank.org/governance/wgi/index.aspx#reports>

- Kirubi, C., Jacobson, A., Kammen, D. M., & Mills, A. (2009, July). Community-Based Electric Micro-Grids Can Contribute to Rural Development: Evidence from Kenya. *ELSEVIER*, 37(7), 1208-1221. doi:DOI: 10.1016/j.worlddev.2008.11.005
- Kouassi, M. (2014, May 14-16). Issues, Challenges and Perspectives of Electrical System Operation, Case Study from Côte d'Ivoire. Abidjan, Lagunes, Côte d'Ivoire. Retrieved from <http://africasmartgridforum2014.org/en/expert/presentationliminaire/mathias-kouassi-presentation-forum-grid-fr.pdf>
- Kranz, J. J., & Picot, A. (2013). Toward Competitive and Innovative Energy Service Markets: How to Establish a Level Playing Field for New Entrants and Established Players. In E. M. Noam, M. L. Pupillo, & J. J. Kranz, *Broadband Networks, Smart Grids and Climate Change* (pp. 157-171). New York: Springer Science+Business Media.
- Manz, D. (2011, November 3-5). Smart Grid Opportunities A Global Perspective. Irvine, California, USA. Retrieved from <http://www.naefrontiers.org/File.aspx?id=32042>
- MIT (Director). (2013). *What is the Smart Grid(s)* [Motion Picture]. Retrieved from <http://ilp.mit.edu/videodetail.jsp?id=760>
- Mtokambali, C. J., & Jun, Z. (2014). Smart Grid Technologies and Future Motivators. *International Journal of Science and Research (IJSR)*, 3(2), 39-43. Retrieved from <http://www.ijsr.net/archive/v3i2/MDIwMTM4Mjk=.pdf>
- Noam, M. E., Pupillo, M. L., & Kranz, J. J. (2013). *Broadband Networks, Smart Grids and Climate Change*. New York: Springer Science+Business Media.
- Patel, N., & Taneja, H. (2014, October 06). *Regulation of Telecom and Electric Power: Divergent History, Common Future?* Retrieved from Greentechgrid: <http://www.greentechmedia.com/articles/read/regulation-of-telecom-and-electric-power-a-common-future>
- Peters, J., Vance, C., & Harsdorff, M. (2011). Grid Extension in Rural Benin: Micro-Manufacturers and the Electrification Trap. *Elsevier*, 39(5), 773-783.
- Population Reference Bureau. (n.d.). *World Population Data Sheet Interactive World Map*. Retrieved October 01, 2014, from http://www.prb.org/Publications/Datasheets/2013/2013-world-population-data-sheet/world-map.aspx#table/western_africa/population/2013
- PPPIRC. (2014, September 30). *Theft / Non-Technical Losses (Water and Electricity)*. Retrieved from PPPIRC: <http://ppp.worldbank.org/public-private-partnership/legislation-regulation/laws/theft-nontechnical-loss>

- Saho, F. B. (2013). Strategic Integration of Renewable Energy in the Regional Market. *ERERA*. Banjul. Retrieved from http://www.erera.arrec.org/getattachment/b1d01f0a-64e2-4494-b8d5-77747e772b3c/Documents/List/English/Session-2_5-Expose.aspx
- The World Bank. (2013). *The Africa Competitiveness Report 2013*. Geneva: World Economic Forum. Retrieved from <http://www.worldbank.org/content/dam/Worldbank/document/Africa/Report/africa-competitiveness-report-2013-main-report-web.pdf>
- TIA Glossary of Telecommunication Terms. (n.d.). *Telecommunication*. (TIA Glossary of Telecommunication Terms) Retrieved 10 24, 2014, from <http://www.tiaonline.org/resources/telecom-glossary>
- U.S. Energy Information Administration. (n.d.). *Glossary*. (U.S. Energy Information Administration) Retrieved 10 21, 2014, from <http://www.eia.gov/tools/glossary/?id=P>
- UN Population Division. (2014). World Urbanization Prospects. New York, New York, USA. Retrieved from <http://esa.un.org/unpd/wup/Highlights/WUP2014-Highlights.pdf>
- University of Kwazulu-Natal. (n.d.). *Eskom Centre of Excellence at UKZN Hosts Smart Grid Research Seminar*. (University of Kwazulu-Natal) Retrieved 10 16, 2014, from <http://www.ukzn.ac.za/news/2014/06/19/eskom-centre-of-excellence-at-ukzn-hosts-smart-grid-research-seminar>
- WAPP. (2011). *About Us*. Retrieved from West African Power Pool: http://www.ecowapp.org/?page_id=6
- WAPP. (2012, September). *Business Plan 2012 - 2015*. General Secretariat. Cotonou: West African Power Pool. Retrieved from [www.ecowapp.org: http://www.ecowapp.org/?page_id=10](http://www.ecowapp.org/?page_id=10)
- Welsch, M., Bazilian, M., Howells, M., & Divan, D. (2013). Smart and Just Grids for sub-Saharan Africa: Exploring options. *Renewable & Sustainable Energy Reviews*, 20, 336-352.
- Yao , Y., Sanogo , A., & Koutoua, C. (2014). General Report Africa Smart Grid Forum 2014. Abidjan, Lagunes, Côte d'Ivoire. Retrieved from http://africasmartgridforum2014.org/en/fichier/rapport-general_forum_africa_smart_grid_en.pdf